2.71

Final examination

3 hours (9am–12 noon)

Total pages: 7 (seven)

PLEASE DO NOT TURN OVER

UNTIL EXAM STARTS

Name: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

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WITH YOUR SOLUTION SHEET(S)

2.71 Optics   **Spring '09**
FINAL EXAMINATION   Tuesday, May 19$^{\text{th}}$, 2009

Duration: 3 hours
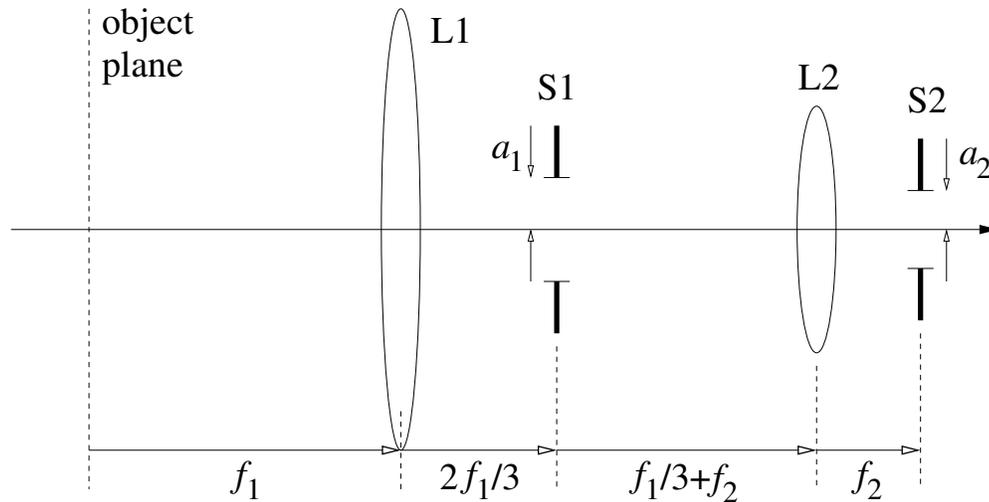
Open books, open notes

Instructions

Treat all problems in one spatial dimension, and neglect apertures unless they are explicitly given in the problem statement. Multiplicative amplitude constants may be neglected when not required by the problem statement.

When a problem seeks a numerical result, you may leave it to a reduced fractional form without doing the numerical division, e.g. 4/7 instead of 0.57143.

When asked to "sketch" an optical system or a function, label your sketch clearly with as much quantitative detail as you can. If you are sketching a complex function, make sure to indicate the real and imaginary parts, or the magnitude and phase.

If a problem appears to be given insufficient data, make assumptions as necessary and state them clearly. When in doubt, make ample use of Occam's razor: "Reasons shall not be multiplied beyond necessity;" *i.e.*, among all possible and adequate explanations the simplest one is the most likely to be correct.

1. **(25%)** For the telescope configuration shown below, where lenses L1 and L2 have focal lengths f_1, f_2, respectively, the object plane and two stops S1 and S2 of half–sizes a_1, a_2, respectively, are at the locations shown,
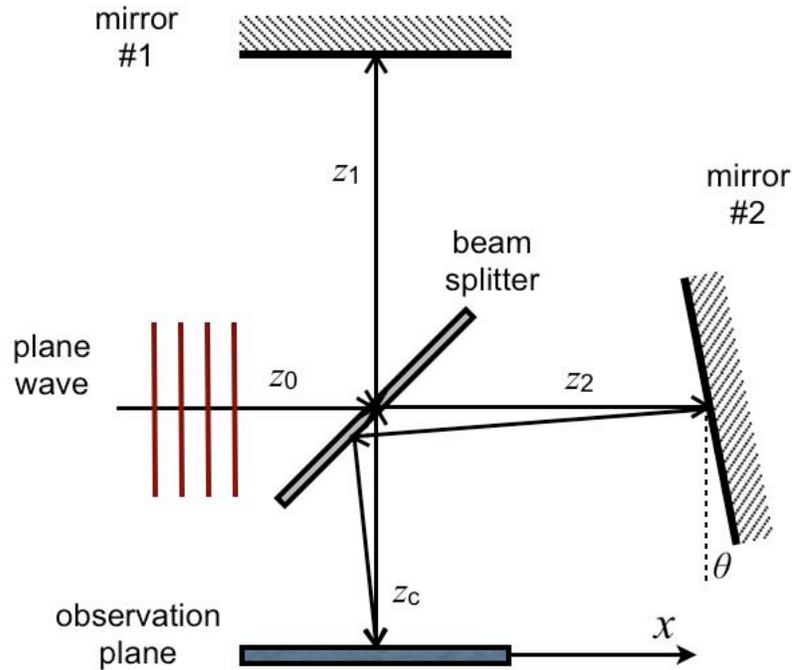

a) identify the Aperture Stop and the Field Stop, and trace the Chief Ray and Marginal Ray for a sample off-axis point object of your choice;

b) locate the Entrance Pupil, Exit Pupil, Entrance Window, and Exit Window;

c) calculate the Numerical Aperture and Field of View; and

d) critique whether stops S1, S2 are optimally located and, if not, suggest better location(s).

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2. (20%) In a single–lens optical imaging system, the object is placed 12cm to the left and the image plane is placed at 8cm to the right of the imaging lens. The medium surrounding the lens is air.

2.a) What should be the focal length of the lens if the image is to be in focus?

2.b) What is the lateral magnification?

2.c) If the numerical aperture (NA) of this optical system is to be 0.1, and there are no other physical apertures in the system, what should be the diameter of the imaging lens?

2.d) If this optical system is illuminated by quasi–monochromatic, spatially incoherent light at wavelength $\lambda = 1\mu$m and using the parameters from the previous questions, what is the Rayleigh (two–point) resolution limit?

2.e) How should the object and image distances of this optical system be modified if the lateral magnification is to equal 1?
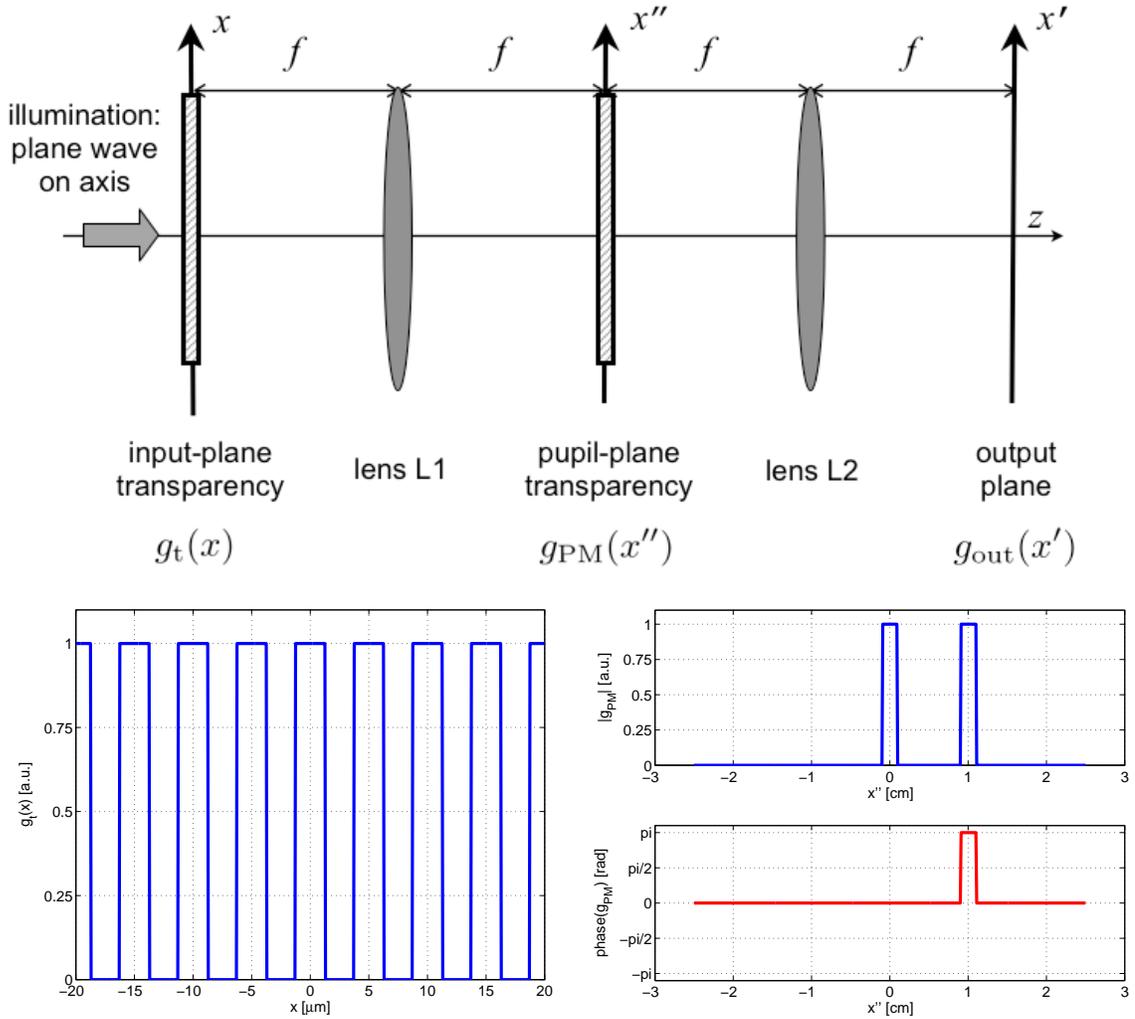
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3. (10%) A Michelson interferometer is illuminated by a perfect plane wave, as shown below. The beam splitter is an infinitely thin partially reflecting mirror of 50% reflectivity. The wavelength is λ. The phase of the spherical wave is defined to equal zero at distance z_0 to the left of the beam splitter. The lengths of the two interferometer arms are z_1, z_2, respectively. Mirror #2 is tilted by an angle $\theta \ll 1$ with respect to the incident wave–vector, as shown. The recombined fields propagate a common distance z_c before reaching an observation plane.

Neglecting the truncation of the plane wave due to the finite size of the optics, write an analytical expression for and sketch the interference pattern as function of coordinate x at the observation plane.

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4. (20%) Consider the imaging system shown below, consisting of two ideal thin lenses L1, L2 with the same focal length $f = 10$cm. Transparency g_t is real and its amplitude transmissivity is shown in the lower left diagram. The complex transmissivity of g_{PM} is shown in the lower right diagram. The illumination is monochromatic at wavelength $\lambda = 0.5\mu$m and spatially *coherent*.

4.a) Propose a physical realization for the complex transparency g_{PM}.

4.b) Calculate the output field $g_{out}(x')$ and intensity $I_{out}(x') = |g_{out}(x')|^2$.

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5. **(25%)** The same optical system of Problem 4 is illuminated by quasi–monochromatic spatially *incoherent* light at wavelength $\lambda = 0.5\mu$m. Calculate:

5.a) the Optical Transfer Function (OTF) and the Modulation Transfer Function (MTF);

5.b) the spatial frequency (or frequencies) that are visible at the output plane and the contrast of the output intensity pattern; and

5.c) the Point Spread Function (PSF) of this spatially incoherent optical system.

GOOD LUCK!

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